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PASTURE STUDIES (XXXI). LIGNIFICATION STUDIES WITH VARIOUS GRASS SPECIES[1]

H. A. STEPPLER[2]

Macdonald College, Que.

[Received for publication August 24, 1950]

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The evidence on the digestibility of lignin varies considerably. Drapala *et al.* (7) studied fecal residues of sheep fed red clover hay. They found that the size of the voided particles increased with advancing maturity and also that staining indicated the particles to be largely lignified. The studies of Watson and Horton (21) showed that sheep excreted lignified cells, apparently unaltered, when fed mature hay. Crampton (3) found a sharp reduction in digestibility of cellulose when lignin values were high. Later Crampton and Forshaw (4) stated that the effect of small increases in lignin upon digestibility of various feed fractions indicates that it is not only the amount of lignin, but the "mode of deposition", that determines the extent of its effect on digestibility and nutritional value of pasture herbage. Lancaster (11) found high negative correlation between per cent of lignin content and digestibility of organic matter, crude fibre and cellulose.

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que. Journal Series No. 271.

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TABLE 1.—STAGES OF DEVELOPMENT, DATE SAMPLED AND INDEX NUMBERS OF EACH SPECIES

TIMOTHY — 1946			TIMOTHY — 1947			BROME GRASS — 1947			REED CANARY GRASS — 1947		
Stage of development	Date sampled	Index No.	Stage of development	Date sampled	Index No.	Stage of development	Date sampled	Index No.	Stage of development	Date sampled	Index No.
Early vegetative plants 8–10″	3rd June	T6–10	Early vegetative plants 8–10″	17th June	T7–10	Inflorescence in sheath, plants 20″	9th June	B7–10	Early vegetative plant 15″ high	4th June	R7–10
Heads formed but not emerged	14th June	T6–20	Heads formed but not emerged	27th June	T7–20	Inflorescence emerged, anthers not dehisced	24th June	B7–20	Late vegetative plant 24″	11th June	R7–20
Heads emerged, anthers not dehisced	20th June	T6–30	Heads emerged, anthers not dehisced	4th July	T7–30	Anthers dehiscing, plant 42″	5th July	B7–30	Inflorescence half emerged, plant 28″	17th June	R7–30
Anthers dehisced still clinging to head	28th June	T6–40	Anthers dehisced still clinging to head	12th July	T7–40	Seeds in early milk, plant 42″	12th July	B7–40	Inflorescence emerged, anthers not emerged, plant 71″	24th June	R7–40
Seeds in early milk	15th July	T6–50	Seeds in early dough	29th July	T7–50	Seeds in late dough	24th July	B7–50	Anthers dehiscing, plant 74″	30th June	R7–50

Patton and Gieseker (15) concluded that lignin was practically undigestible. Ferguson (8) reached the same conclusions after working with wheat straw pulp, while Crampton and Maynard (5) recovered 97.8 per cent and 99.3 per cent of dietary lignin in the faeces of rabbits and steers respectively. Hale *et al.* (9) found that digestibility of lignin in alfalfa hay varied from −5.1 per cent to 23.7 per cent. Davis *et al.* (6) reported apparent digestibility of lignin of pea vines to be 16.2 per cent and of lima bean vines to be 10.6 per cent when fed to sheep. Rutledge and Common (19) reported the digestion coefficient of lignin of unthreshed ryegrass saved for seed to be 5.3, while that of ryegrass hay cut at normal hay stage was 12.2.

It has been reported by three independent workers, Prjanischnikow and Tomme (17), Ferguson (8) and Homb (10) that chemical treatment of straw increased the digestibility of the other constituents. This was attributed largely to either removal of part of the lignin or "freeing" the cellulose from the physical bondage of the lignin.

In view of the fact that lignin is believed to occlude from digestion any cytoplasm or other nutrient that it surrounds, and also, that it may have an adverse effect on digestion of some constituents, especially cellulose in the lignified cell wall, an attempt was made to measure quantitatively the areas in the stems that may be excluded from digestion by reason of the lignification that had taken place.

MATERIAL AND METHODS

Species Used

Three grasses were used in this study: Timothy (*Phleum pratense* L.), Brome grass (*Bromus inermis* Leyss.) and Reed Canary grass (*Phalaris arundinacea* L.). The study was divided into two parts, a histological phase which involved all three species, and a nutritional phase which was conducted on Timothy.

Collections Made and Method of Presentation

The grasses were collected at various stages of maturity ranging from early vegetative to inflorescence turning brown with seeds in early dough. Each stage collected was sampled at three locations on the stem, viz., one-quarter inch below the second node, one-quarter inch below the fourth node and two inches above the sixth node. Ten plants were collected for each stage, the appropriate samples being preserved in formaldehyde acetic acid (F.A.A.) fixative.

The stages of maturity at which collections were made for each species are given in Table 1. Timothy hay for feeding trials was collected in 1947. This corresponded to the last three stages of development; approximately 400 pounds of air dried hay for each stage was obtained and stored in the barn.

The sections were taken from the F.A.A. and dehydrated through the normal butyl alcohol series as outlined by Sass (20). The material was infiltrated with 56°–58° tissuemat and subsequently sectioned on a microtome at 10 microns. They were then stained with safranin and counter-

stained with Fast green, using the normal staining schedule. The length of immersion in counterstain was carefully timed to 90 seconds so that materials would be comparable.

Indexing System

Since it was anticipated that at least five hundred slides would be examined, an indexing system was devised. The index number consisted of three parts, thus:

Part 1. Contained a letter to refer to the species and a number for the year of collection, i.e., T—timothy; B—brome grass; R—reed canary; 6—1946; 7—1947.

Part 2. Contained a two digit figure—the tens figure indicates stage of maturity, i.e.,

10 — first stage of maturity
20 — second stage of maturity
30 — third stage of maturity
40 — fourth stage of maturity
50 — fifth stage of maturity.

The units figure indicates the location on the stem, i.e.,

01 — $\frac{1}{4}''$ below the second node
02 — $\frac{1}{4}''$ below the fourth node
03 — $2''$ above the sixth node.

Part 3. Contained a three digit figure—the hundreds figure indicates the sample number, while the tens and units figure indicates serial number of the slide.

An example of a complete index number will be found in Figure I, viz., T7 – 31 – 401, which indicates: the section is of timothy, taken in 1947, at the third stage of maturity (see Table I), and finally this was the first slide in the series from sample No. 4.

Index numbers for each stage of each species are shown in Table I.

As previously stated, an attempt was made to measure quantitatively the amount of lignified tissue. In order to overcome the personal factor the following procedure was used:

(1) The cross-section is projected through a microscope on to white paper of a good grade bond—the cross-section being enlarged to about 12–16 inches in diameter.

(2) The cross-section as projected is outlined on the paper. Then all lignified areas are outlined, using a sharp pointed pencil. An example of a tracing is shown in Figure I.

(3) The entire cross-section is first cut out of the paper and then weighed. The lignified areas are likewise cut out and weighed. From these weights the percentage area of lignified tissues is calculated. At least five such measurements were made for each stage and location, the average of these measurements being reported herein.

Feeding Trials

The hay collected was chopped in a feed chopper and subsequently fed to sheep during the winter of 1947–48 through the co-operation of the Department of Nutrition of Macdonald College. Six lambs were used,

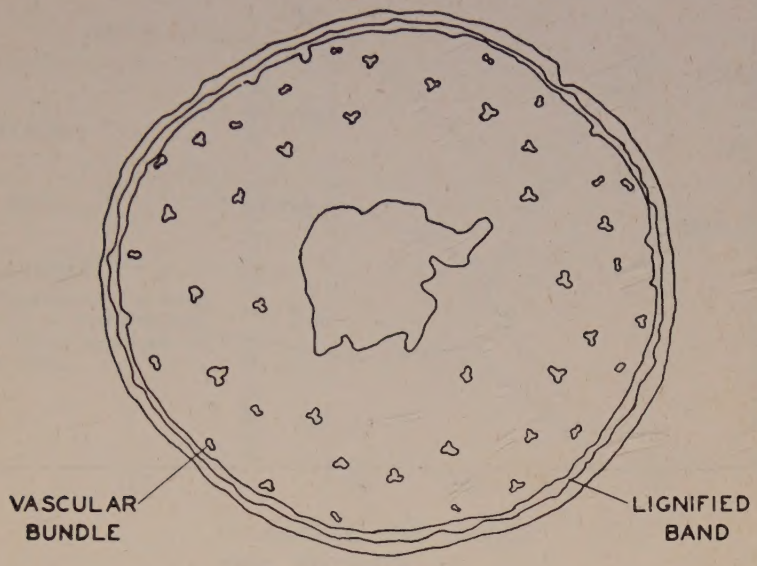

FIGURE 1. Tracing of projected cross section

each group of two being fed one of the cuts. Three collection periods were run so that all lambs eventually received each cut. Faeces and urine were collected and weighed daily. A small portion of feed was refused by the animals; this was included with the faeces when digestibility was calculated.

Samples of faeces were preserved in 0.2 per cent mercuric chloride solution. They were then prepared for staining following the procedure of Drapala *et al.* (7). The samples were then stained with safranin and counterstained with Fast green for two periods—90 seconds and 3 minutes.

RESULTS AND DISCUSSION

Sequence of lignification

Investigation showed that lignin appeared first in the xylem vessels of the vascular bundles. As the plant reaches maturity the cells in the spaces between the vessels in any one bundle gradually become lignified; also, a band of lignified cells appear at the perimeter of each bundle. Early in the life of the plant a band of lignified cells—sclerenchyma tissue—forms immediately beneath the epidermis. This sequence is in agreement with findings of other workers, e.g., Norman (12) and Philips *et al.* (16).

Lignification in the Timothy Stem

A graph showing the percentages of lignified area at three locations on the stem and five stages of maturity is given in Chart I for 1946 and Chart II for 1947 data. Line 01 shows the trend in lignification at the base; it will be noted that there is very little lignified area at early stages. This increases until the inflorescence has emerged—stage 30, in Table I. After that,

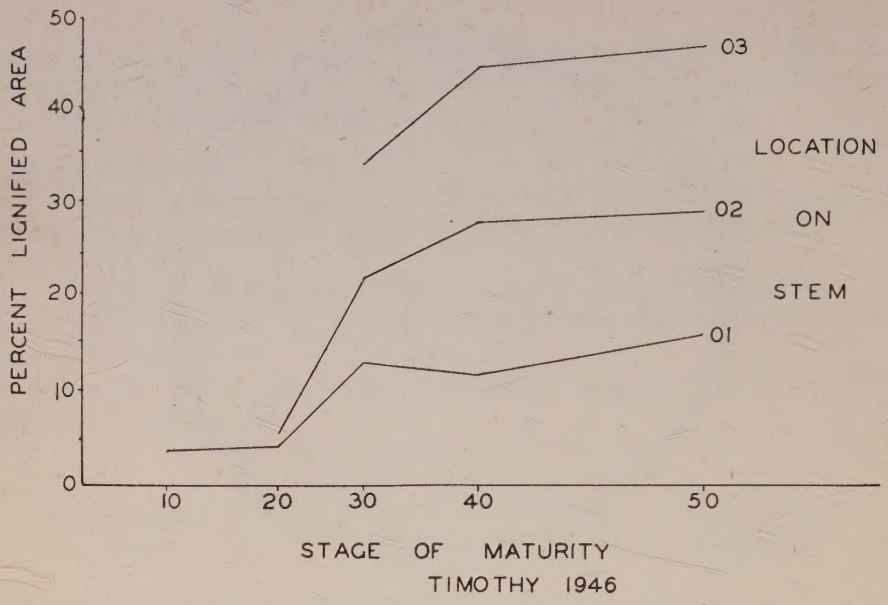

CHART I. Lignified area at five stages of maturity and at three locations on the stem.

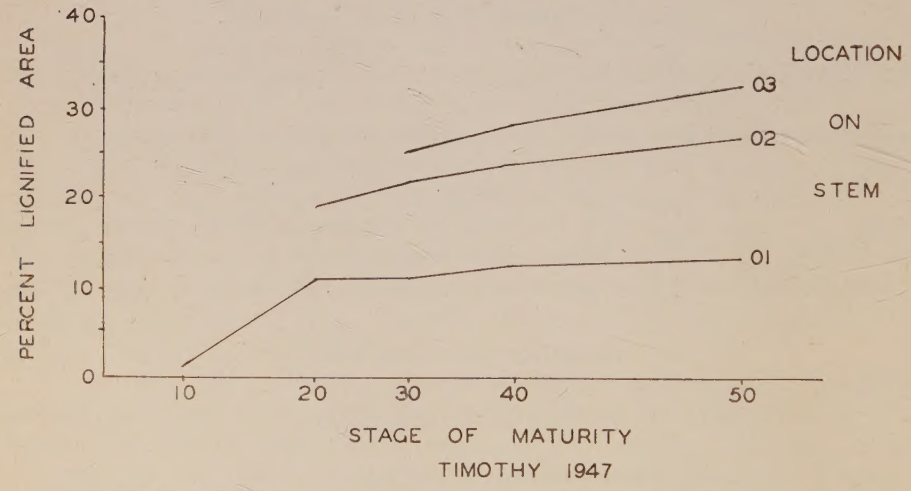

CHART II. Lignified area at five stages of maturity and at three locations on the stem.

there is very little increase in amount of lignified area. These lignified areas are composed of the vessels of the vascular bundles, the bands of lignified cells around the perimeter of the bundle and the band of sclerenchyma tissue beneath the epidermis.

Line 02 shows the trend in lignification at the centre of the stem. It will be noted the per cent of lignified area follows a similar trend as at the base. The 1946 data indicate a marked increase up to stage 40 and then no appreciable change—the 1947 data show increases which are not quite so pronounced.

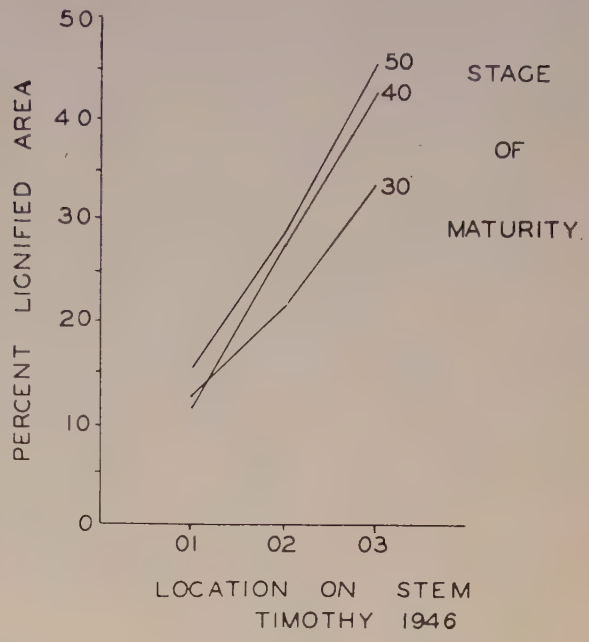

CHART III.

Lignified area at three stages of maturity and at three locations on the stem.

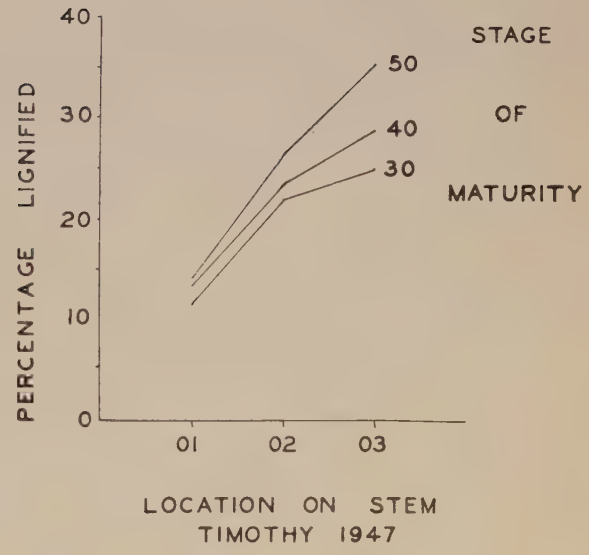

CHART IV.

Lignified area at three stages of maturity and at three locations on the stem.

Line 03 on the graphs portrays the trend in lignification at the top of the stem. It will be noted that there is a sharp increase between stages 30 and 40, with little change after stage 40, i.e., after the anthers have dehisced.

Charts III and IV present the same data, only in this instance showing the trend from the base to the top of the stem for each stage of maturity.

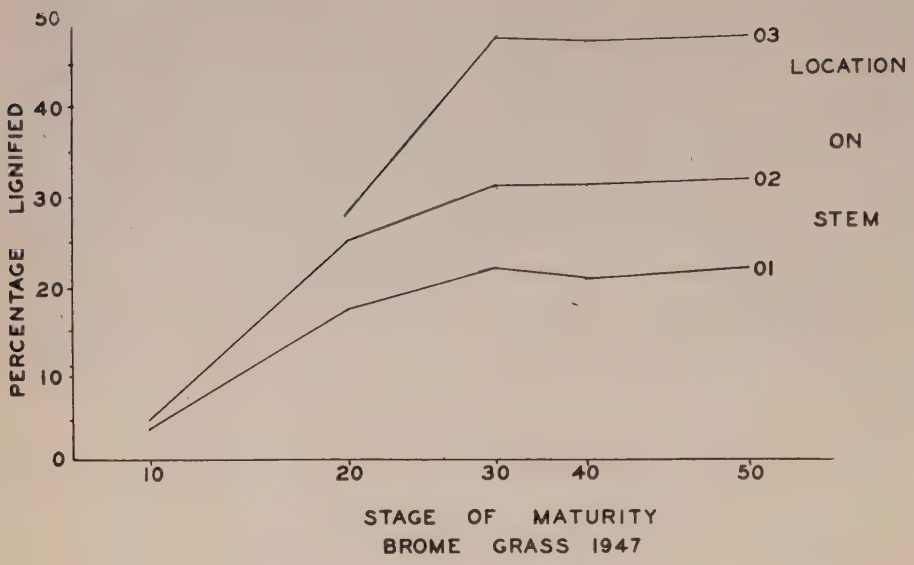

CHART V. Lignified area at five stages of maturity and at three locations on the stem.

The graph lines for the 1946 material are practically parallel. It will be noted that the percentage of lignified area increases sharply from the base to the top of the stem. This is evident for all stages of maturity and for both years. The stems were mostly solid at the base with the lignified area confined to the vascular bundles and a thin band of sclerenchyma tissue beneath the epidermis. As one progressed up the stem, it became hollow, the band of sclerenchyma tissue thickened and many of the vascular bundles coalesced with it.

The 1947 data showed similar trends, although the graph lines do not exhibit the degree of parallelism found in the 1946 data.

Feeding Trials with Timothy Hay and Faeces Examination

The feeding trials previously mentioned were carried out by E. W. Crampton, Chairman, and I. Lucas, graduate assistant, of the Department of Nutrition of Macdonald College.

Their co-operation in this phase of the project is gratefully acknowledged.

The summarized results are presented in Table 2.

TABLE 2.—DIGESTIBILITY OF DRY MATTER OF TIMOTHY HAY

——	Stage 30	Stage 40	Stage 50
% Digested dry matter	64.9	51.0	46.0
% Undigested dry matter	35.1	49.0	54.0
Lb. of feed refused	0.3	1.6	1.9

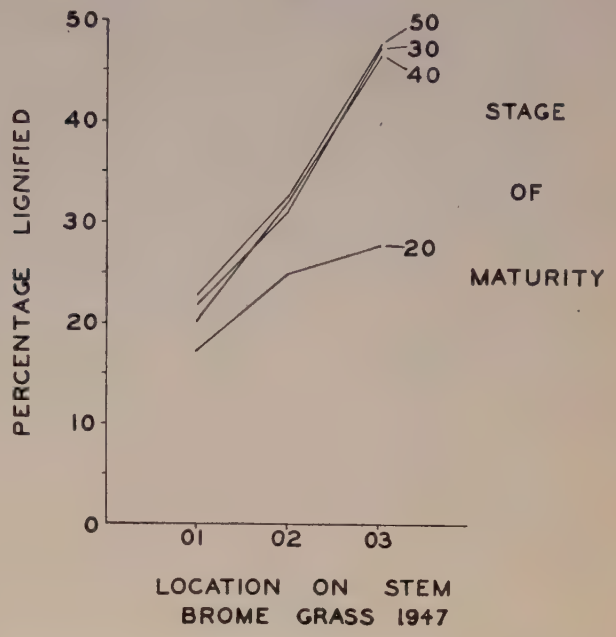

CHART VI.

Lignified area at four stages of maturity and at three locations on the stem.

As the maturity increased, the hay became less digestible. Also, the refused hay could be interpreted as indicating a decrease in palatability as the hay matured.

An ocular examination of the faeces showed that the size of the undigested voided particles increased in size and numbers in the latter stages of maturity. Examination of the fecal slides supported this observation. Despite the increase in the counter-staining period, no evidence of unlignified tissue could be found in the voided material. The majority of the particles appear to be sections of the sclerenchyma band and of the vascular bundle.

Lignification in Brome Grass Stem

The trend in lignification follows that previously described for Timothy. Chart V shows the trend in lignification at each of three locations on the stem for the various stages of maturity of Brome grass.

Line 01 shows the trend at the base of the plant. At the earliest stage the lignified area comprised only the vascular bundles. The percentage of lignified area increased rapidly to the second stage of maturity and then very little change was noted in the later stages. The increases noted were brought about by the appearance of the band of sclerencyma tissue.

The trend in lignification at the centre of the stem is presented in line 02 of Chart V. This follows that observed at the base of the plant, with the greatest increase found between stages 10 and 20.

Line 03 of the Chart V portrays graphically the changes in lignification at the top of the stem. A marked increase was noted from stages 20 to 30; no appreciable changes were found in subsequent stages.

Chart VI shows the lignified area at the three locations of the stem for the last four stages of maturity. Stage 20 definitely had the least lignified area, while 30, 40 and 50 are practically identical. In each instance, the

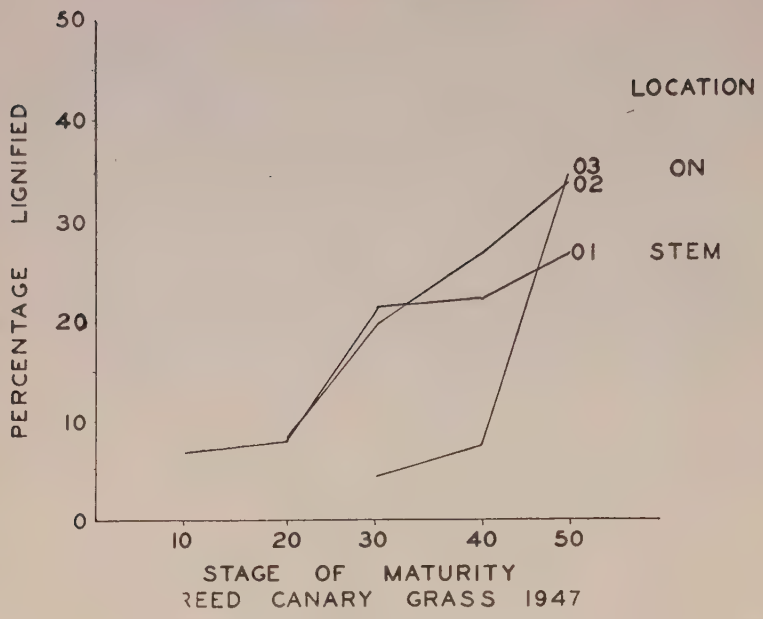

CHART VII. Lignified area at five stages of maturity and at three locations on the stem.

least amount of lignified area was found at the base and the greatest at the top of the stem. Increases in the amount of lignified area were brought about by: (1) an increase in the thickness of the band of sclerenchyma, (2) the coalescing of the vascular bundles with this band, noticeably near the apex of the stem and (3) a progressive reduction in the total area of plant tissue toward the top of the stem.

Lignification in Reed Canary Grass Stem

A graphical presentation of the lignification at each location on the stem for the stages of maturity collected in Reed Canary grass is shown on Chart VII. Line 01 indicates a gradual increase at the bottom of the stem for each stage collected—very little change from stage 10 to 20, a sharp increase from 20 to 40, and another marked rise from 40 to 50.

Line 02 indicates a steady and rapid increase from stage 20 to stage 50 at the centre of the stem.

Line 03 shows a slight increase from stage 30 to 40 and then a very rapid increase from stage 40 to 50. These increases are due to the rapid laying down of lignin in the sclerenchyma band at the apex of the stem.

Graphical presentation of the data from the base to the apex of stem is given in Chart VIII.

Examination of this chart shows that at stage 30 the greatest amount of lignified area is at the base with the least at the top. At stage 40 the greatest amount is at the centre of the stem with the least at the apex, while in stage 50 the greatest amount is at the apex and the least at the base.

The increases from base to apex were due to the appearance of lignin to form the sclerenchyma band. This took place very rapidly once the

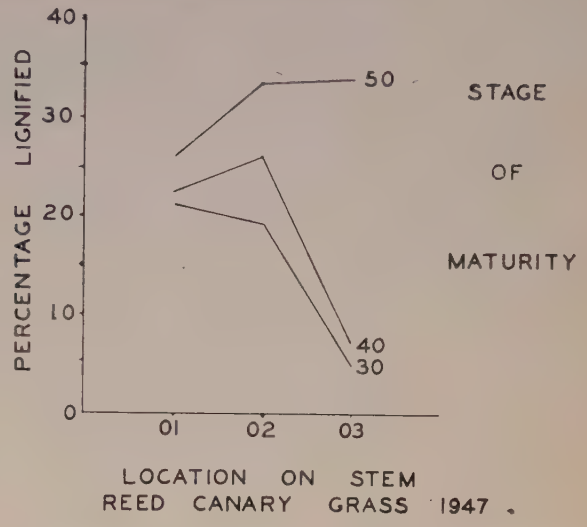

CHART VIII.

Lignified area at three stages of maturity and at three locations on the stem.

period of rapid growth had ceased. From stage 30 to 40 the plant grew from 28 inches to 71 inches in seven days, while from stage 40 to 50 the plant height increased from 71 inches to 74 inches in six days.

DISCUSSION

It is apparent in all cases that, early in the life of the plant, while in an actively growing condition, very little lignification took place. The appearance of the inflorescence signalled an end of rapid elongation. This was followed by a sharp increase in the amount of lignified area. A saturation point seemed to be soon reached, because after the formation of seed very little increase in the lignified area took place.

This would indicate, in the case of Timothy, that if it could be cut for hay after rapid elongation has ceased and before the anthers dehisce, a more highly digestible product could be obtained. The digestibility trials support this observation.

As stated previously in this report, an attempt was being made to determine the amount of plant tissue which would be undigested in a normal feeding trial. Examination of the fecal slides showed that apparently only lignified portions were passing through the digestive tract intact. The digestibility trials showed decreasing digestibility with increasing maturity, while the refused portion of feed indicated decreasing palatability with advancing maturity.

The values of undigested material in Timothy from the lignification studies were averaged for each stage, since there were three locations at each stage, and compared to the undigested dry matter as obtained in the feeding trial; these figures are presented in Table 3. It is apparent that the value calculated from this lignification study does not account for all the undigested material found in the feeding trial. However, it is significant that for each stage it accounts for approximately 50 per cent of the dry matter. A cursory examination may lead one to believe that the original hypothesis is wrong; however, closer investigation shows this is not neces-

sarily true. *First*, the lignification study was confined to stems only—no account being taken of leaf blade, leaf sheath or leaf to stem ratio. *Second*, in reaching the average values shown in line (2) of Table 3, the value for each location on the stem was treated as representing equal portions of stem. Actually the length of the internodes increases towards the apex of the stem so that the values for the centre and top of the stem should be given greater weight than those of the base. It seems reasonable to assume that the calculated value is an underestimation of the true value.

TABLE 3.—UNDIGESTED DRY MATTER IN TIMOTHY AS CALCULATED FROM FEEDING TRIALS AND LIGNIFICATION STUDY

——	Stage 30	Stage 40	Stage 50
(1) % undigested D.M. (feeding trial)	35.1	49	54
(2) % assumed undigested (lignification study)	19.0	22	26
(3) % (2) is of (1)	54.0	45	48

Examination of the data on Brome grass indicates that a maximum amount of lignified tissue will have been produced by the time the anthers start to dehisce and thereafter little change can be anticipated. Thus, a more desirable hay could be obtained if cut as soon as the inflorescence has appeared, but before dehiscence of the anthers, i.e., B7–20, Table 1.

The situation in Reed Canary grass is somewhat similar. Examination of Table 1 shows that at R7–30 the plant was 28 inches tall, at R7–40 seven days later it was 71 inches tall, while at R7–50 six days later it was only 74 inches tall. Further examination of the cross section shows that during the period of very rapid elongation lignin was laid down only in the vascular bundles—this is shown by the downward slope of lines 30 and 40 on Chart VIII. Thus, if the crop could be cut for hay as soon as possible after stage 40 is reached, then a much superior product would be produced. This optimum condition with reference to lignified tissue lasts for a very short period.

TABLE 4.—LIGNIFIED AREAS IN TIMOTHY, BROME AND REED CANARY GRASS AT SIMILAR STAGES OF MATURITY

——	Timothy	Brome	Reed Canary	——
Base	11.9	17.9	22.1	Inflorescence completely emerged, anthers not dehisced.
Centre	21.2	24.7	26.5	
Top	24.9	27.4	7.1	
Average	19.0	23.0	18.6	
Base	12.6	22.1	26.4	Anthers dehiscing
Centre	22.9	31.1	33.6	
Top	28.2	47.1	33.9	
Average	21.2	33.4	31.3	

It is apparent if one compares charts II, IV, VI and VIII that differences exist between the various species. The slope of the lines on these charts would indicate similarity between Timothy and Brome, while Reed Canary grass is decidedly different. The rate of growth in Timothy and Brome is such that lignification of the vascular bundles and sclerenchyma tissue is concurrent with the elongation of the stem. In Reed Canary grass the rate of elongation was so rapid that lignin was laid down in only the vascular bundles. This resulted in the situation found in early stages where less lignin was observed at the apex than at the base. However, as soon as rapid growth ceased, the situation in Reed Canary became similar to that of Timothy and Brome grass, viz., more lignin at the apex than at the base.

A comparison of the average percentage of lignified areas for the three species at similar stages of maturity is given in Table 4.

It will be noted that at the first stage of maturity the three species are similar, with Brome having the greatest amount of lignified area. At the second stage, however, Timothy is definitely superior, having changed little from the first stage, while Brome and Reed Canary have materially increased and are virtually the same.

This evidence would indicate that the period for harvesting Timothy for hay is not as critical as that of Brome or Reed Canary grass. If Reed Canary could be cut at the proper time, a product equal to, or possibly superior to, Timothy hay would result.

SUMMARY AND CONCLUSION

A method of estimating quantitatively the percentage of lignified area in the stem is described.

The trend in lignification in Timothy and Brome grass proved to be similar, an increase in percentage lignified tissue from the base to the top of the stem and an increase in percentage lignified with advancing maturity, the rate of increase being slower once the seeds started to form.

The trend in lignification of Reed Canary grass showed that in the early stages during the period of rapid growth the least amount of lignified area was found at the apex. As soon as rapid growth ceased the picture changed and then resembled that of Timothy and Brome, i.e., the greatest amount of lignin at the apex and the least at the base.

The study of the fecal slides indicated that the plant tissue undigested by the animal is lignified. The amounts of undigestible plant tissue, as calculated by the method described herein, account for approximately 50 per cent of the undigested matter as determined by sheep feeding trials.

There is a possibility that an index of digestibility may be obtained, using this quantitative method of estimating percentage of undigestible area and correlating it with the results of actual feeding trials.

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MOISTURE REGIONS IN THE EAST KOOTENAY LOWLANDS OF BRITISH COLUMBIA[1]

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Not more than five per cent of the Province of British Columbia is low enough in elevation and at the same time gentle enough in relief to permit cultivation of the land. In view of the limited extent of arable land, and the advanced development of the lumbering and mining industries in the province, one might expect that this land would be well developed agriculturally wherever it lies close to markets or to major routes of transportation; but some of the best-located units of good land to-day remain undeveloped and almost empty, because of certain handicaps which have proven to be difficult to surmount.

One of these handicaps has been an unfortunate characteristic of the climate of the growing season—a combination of low precipitation and high frequency of frost. On the one hand, the low precipitation makes desirable or necessary the use of irrigation for the production of crops. On the other, the high frost frequency prevents the development of a specialty-crop agriculture, which could cover adequately the costs of irrigation, such as has taken place in the even drier Okanagan Valley to the west.

A district which features much land that suffers from this climatic handicap is the East Kootenay, in the far southeast of the province. Passing through the district is the Rocky Mountain Trench, an undulating to rolling belt of land with an elevation of from two thousand to thirty-five hundred feet (Figure 1). Along with certain tributary valleys, the Trench has in this district many thousands of acres which, from the point of view of elevation and topography, are potentially arable. These acres, however, suffer from both drought and high frost frequency during the growing season. Chiefly as a result of this climatic condition, the land is to-day largely undeveloped and with only a very scattered agricultural population.

Since the factor of growing-season precipitation is so critical to areas like the East Kootenay lowlands, minor regional variations in moisture conditions inside the area are of definite economic significance and are worthy of study. That such variations occur has been observed by many through available statistics of climate-recording stations, variations in vegetative cover, and extent of success in dry-farming in different parts of the area. However, the accurate identification and location of different moisture climates inside the given area have proven to be very difficult because of the scarcity of climate stations and the limited extent of agricultural practice. It is the purpose of this paper to present a method for the identification and location of moisture climates in these critical areas, as applied to the lowlands of the East Kootenay.

[1] The field work for this paper was carried out during the summers of 1948 and 1949 when the author was engaged in field survey work on land utilization and property values in the district for the British Columbia Department of Lands.

* Deceased.

TABLE 1.—DATA FOR CLIMATE-RECORDING STATIONS IN THE EAST KOOTENAY LOWLANDS

	Annual	January	February	March	April	May	June	July	August	September	October	November	December
Newgate (altitude 2,420′)													
Temperature	43	19	25	35	45	53	59	66	63	54	44	31	22
Precipitation	13.67	1.40	1.06	0.91	0.77	1.25	1.66	0.87	0.85	0.90	1.08	1.29	1.63
Water deficiency	11.9	—	—	—	—	—	1.4	4.7	3.7	1.9	0.2	—	—
Water surplus	1.9	0.3	1.1	0.5	—	—	—	—	—	—	—	—	—
Cranbrook (altitude 3,015′)													
Temperature	41	17	21	33	43	51	58	64	62	52	42	29	20
Precipitation	14.45	1.45	1.11	0.82	0.67	1.26	1.94	1.10	1.01	1.13	1.00	1.36	1.60
Water deficiency	10.8	—	—	—	—	—	1.4	4.2	3.4	1.6	0.2	—	—
Water surplus	2.1	0.4	1.1	0.6	—	—	—	—	—	—	—	—	—
Wasa (altitude 2,560′)													
Temperature*	42	18	23	34	44	52	59	65	62	52	43	30	21
Precipitation	14.37	1.33	1.10	0.77	0.69	1.36	1.92	0.79	1.08	1.17	1.28	1.23	1.65
Water deficiency	10.4	—	—	—	—	—	1.2	4.5	3.3	1.4	—	—	—
Water surplus	1.7	0.1	1.1	0.5	—	—	—	—	—	—	—	—	—
Canal Flats (altitude 2,680′)													
Temperature*	41	16	21	32	43	51	58	64	61	51	41	28	19
Precipitation	16.26	1.54	1.21	1.04	0.82	1.51	2.19	1.24	1.28	1.25	1.14	1.46	1.58
Water deficiency	9.3	—	—	—	—	—	0.7	4.1	3.1	1.4	—	—	—
Water surplus	2.7	0.6	1.2	0.9	—	—	—	—	—	—	—	—	—
Kingsgate (altitude 2,690′)													
Temperature*	43	20	25	34	44	52	58	65	63	54	44	32	23
Precipitation	21.21	2.84	1.90	1.54	1.33	1.78	1.89	0.81	0.89	1.33	1.62	2.21	3.07
Water deficiency	9.3	—	—	—	—	—	—	4.3	3.6	1.4	—	—	—
Water surplus	7.4	2.8	1.9	1.2	—	—	—	—	—	—	—	—	1.5
Elko (altitude 3,080′)													
Temperature	41	18	22	33	43	51	58	64	62	52	42	29	21
Precipitation	19.89	2.36	1.11	1.31	1.28	1.63	2.79	1.39	1.30	1.61	1.71	1.51	1.89
Water deficiency	7.8	—	—	—	—	—	—	3.6	3.1	1.1	—	—	—
Water surplus	4.7	2.4	1.2	1.1	—	—	—	—	—	—	—	—	—
Fernie (altitude 3,310′)													
Temperature	40	18	20	30	41	50	56	62	60	51	42	29	20
Precipitation	38.92	4.81	3.65	3.32	2.36	2.63	2.96	1.58	1.54	2.55	3.93	4.07	5.52
Water deficiency	3.5	—	—	—	—	—	—	1.6	2.7	—	—	—	—
Water surplus	21.1	4.8	3.6	3.3	1.1	—	—	—	—	—	—	2.8	5.5

* Estimated.

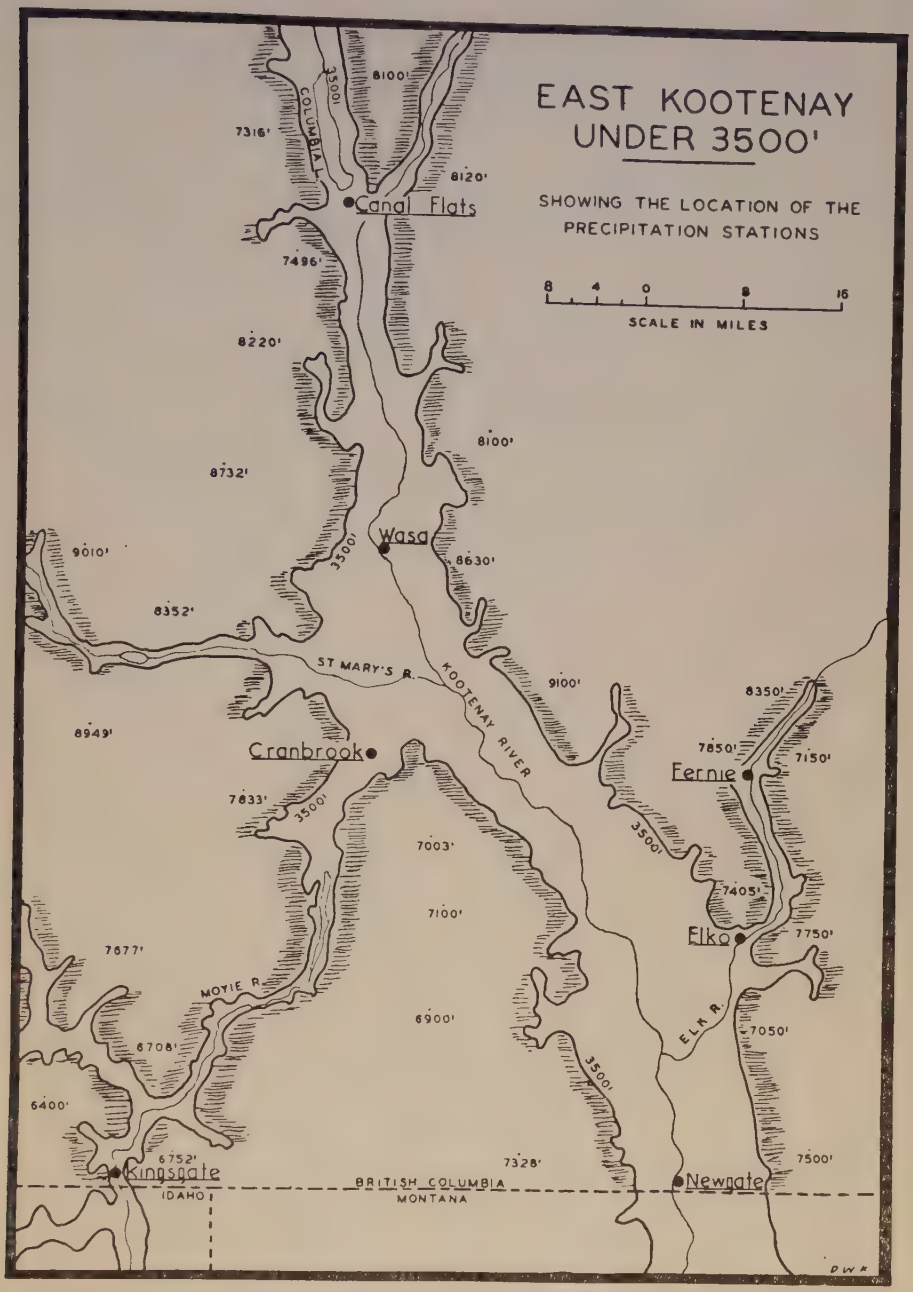

FIGURE 1

TYPES OF MOISTURE CLIMATES AS INDICATED BY AVAILABLE STATISTICS

That part of the East Kootenay district lying below thirty-five hundred feet elevation features seven climate-recording stations (Figure 1). Three of them, Newgate, Wasa and Canal Flats, lie on the Kootenay River in the heart of the Trench, and in the south, middle and north of the district.

Two others, Cranbrook and Elko, lie on the sides of the Trench at the mouths of tributary valleys. The remaining two, Kingsgate and Fernie, lie far up these tributary valleys from Cranbrook and Elko respectively.

In Table 1 are listed the available temperature and precipitation figures for the seven stations, month by month. In addition are given the figures of winter precipitation surplus and summer precipitation deficiency, calculated from the temperature and precipitation figures according to the method described by C. W. Thornthwaite (1). In essence the winter surplus figures represent the amount of accumulated winter moisture available in the spring as soil reserve for tree growth, and the water deficiency figures represent the amount of extra precipitation needed for successful dry-farming agriculture.

While the seven stations represent seven different conditions of moisture, it is possible to distinguish three broad climate types. One of these prevails at the three stations of Newgate, Cranbrook and Wasa. Their annual precipitation of about fourteen inches differs by less than one inch. The May-September period, the most significant for plant growth, has in each case somewhat less than half the total precipitation, a June maximum, and a distinctly dry July-August period. Water deficiency occurs from June to September, and the winter water surplus is distinctly small. In other words, there is a severe shortage of water during the growing season which is not offset by a wet winter. Verbal and written information on the history of farming around the three stations indicates that the prevailing climate is marginal for the dry-farming of grain, and is definitely too dry for hay and specialty crops without the use of irrigation water from early June onward.

The opposite extreme to this dry climate in the East Kootenay lowlands is the humid type which prevails at Fernie. Fernie receives some thirty-nine inches of rain a year. Nearly three-quarters of it falls in the winter period, giving the station a very high winter water surplus figure. Only July and August show a water deficiency, which totals less than five inches. Farmer-experience has shown that July and August are "safe" for grain crops; in some years there is adequate rain for hay and specialty crops, while in others irrigation water is needed for a few weeks. (Mean deviation from normal is over twenty-five per cent at all seven stations).

From the point of view of annual precipitation, a transitional climate prevails in the vicinity of the three remaining stations of Canal Flats, Kingsgate and Elko. Canal Flats and Elko have a yearly precipitation distribution much like that at the three dry-climate stations; and indeed it would appear arbitrary whether Canal Flats be linked with them or with Elko. Kingsgate, on the other hand, has a Fernie-type distribution, with a relatively high winter water surplus. But Elko and Kingsgate have a significant thing in common—there is no water deficiency until July. Once again this interpretation of the figures is borne out by farmer-experience.

From the point of view of agriculture, therefore, three moisture climates can be distinguished on the basis of intensity of growing-season water deficiency and length of the water-deficient period. These may be defined as follows:

Dry type (Newgate, Cranbrook, Wasa)—Water deficiency over ten inches, and prevailing from June to September; irrigation needed for all types of farming through most of the growing season.

Intermediate type (Elko, Kingsgate, and Canal Flats marginal)—Water deficiency five to ten inches, prevailing from July to September; irrigation necessary for most crops after the first of July.

Humid type (Fernie)—Water deficiency less than five inches, and limited to July and August; irrigation needed only in certain years, and for hay and specialty crops only.

From the point of view of forest growth, which is dependent on the water surplus of winter rather than the water deficiency of summer for its character, the above climatic division is also applicable. Thus the three dry-summer stations of Newgate, Cranbrook and Wasa have a winter water surplus of under 2.5 inches, while the humid-climate station of Fernie has a very high surplus—over twenty inches. The stations of Canal Flats, Elko and Kingsgate are intermediate, with surpluses of 2.5 to ten inches, with Canal Flats again taking a marginal position. It can, therefore, be said that on the lowlands of the East Kootenay district variations in the forest cover will reflect the variations in intensity of summer drought.

It is this correlation between vegetation and summer water deficiency that made possible the drawing of a detailed climate map of the East Kootenay lowlands which would describe regionally the irrigation needs of the area. A reconnaissance survey revealed that the total vegetative cover reflected climate contrasts in the vicinity of the seven stations, and indicated that the cover found for each climate would mark the presence of that climate in other parts of the East Kootenay. Steps were taken, therefore, to establish as detailed a relationship as was possible between vegetative cover and climate at the seven stations.

THE FIELD METHOD USED TO SUMMARIZE THE VEGETATIVE COVER AT THE SEVEN CLIMATE STATIONS

Field studies were made of the vegetative cover on more than two hundred acre plots in the vicinity of the seven stations. The plots were located not in any geometric pattern, but in such a way as to cover all possible conditions of soil and exposure. A soil survey of the East Kootenay district was being carried on at the time by the Soils Division of the British Columbia Department of Agriculture, so that it was possible to make a fairly accurate appraisal of soil-vegetation relationships at each station.

Five types of site, reflecting different degrees of land moisture as related to soil and moisture conditions, were distinguished:

Normal sites—Deep sandy loam to silt loam soils, neutral to somewhat calcareous, with gently undulating topography; lighter soils with a north to northeast exposure.

Moist sites—Deep clay-loam soils; soils with a relatively impervious subsoil; closed depressions without sub-irrigation; north-facing slopes with deep loamy soils.

Very moist sites—Land sub-irrigated during most or all of the growing season.

Dry sites—Deep loamy sand to gravel soils; soils with sand or gravel subsoil; south-facing slopes with loamy soils.

Very dry sites—Highly calcareous soils with a very porous but impenetrable subsoil.*

Highly specialized sites, such as the beds of temporary streams, were not considered.

Four aspects of the vegetative cover were studied: (1) The virgin cover, as expressed in stumps; (2) the second-growth cover, which to-day makes up the bulk of the forest; (3) shrubs, and (4) forbs. In the case

* This description refers to a phase of the Elko soil catena, in which a topsoil of gravelly loam is underlain at a depth of six to ten inches by a layer of very concentrated lime.

TABLE 2.—VEGETATION FRACTIONS FOR THE CLIMATE STATIONS

Dry climate

(Newgate, Cranbrook, Wasa)

Very dry sites	Dry sites	Normal sites	Moist sites	Very moist sites
Co (PP)	C1 $\frac{90}{PP}$ $\frac{10}{DF}$ (WL)	C1 $\frac{50}{PP}$ $\frac{40}{DF}$ $\frac{20}{WL}$	C2 $\frac{60}{DF}$ $\frac{20}{PP}$ $\frac{20}{WL}$	C3 $\frac{40}{BC}$ $\frac{30}{ES}$ $\frac{20}{Asp}$ $\frac{10}{DF}$
similar	similar	similar (LP)	sim. & LP (Asp)	?
none	AB	AB	AB-She (Cea)	Wil Dog RMM
DB	DB (Bea)	DB Bea	Bea	Twi

Intermediate climate

(Elko; Kingsgate and Canal Flats in part)

SAME AS ABOVE	C1 $\frac{50}{DF}$ $\frac{40}{PP}$ $\frac{10}{WL}$	C2 $\frac{50}{DF}$ $\frac{30}{WL}$ $\frac{20}{PP}$	C3 $\frac{50}{DF}$ $\frac{40}{WL}$ (PP ES WP)	SAME AS ABOVE
	similar (LP)	sim. & LP (Asp)	sim. & LP Asp WB	
	AB	AB-She Cea	She Cea RMM Thi	
	Bea DB	Bea	Twi Cor Bea	

Humid climate

(Fernie)

?	C2 $\frac{50}{DF}$ $\frac{40}{WL}$ $\frac{10}{PP}$	C3 $\frac{50}{DF}$ $\frac{40}{WL}$ $\frac{10}{ES}$ (RC WP)	C3 $\frac{30}{ES}$ $\frac{20}{RC}$ $\frac{20}{DF}$ $\frac{20}{WL}$ $\frac{10}{WP}$ (AF WH BC)	C3 $\frac{40}{BC}$ $\frac{30}{ES}$ $\frac{20}{Asp}$ $\frac{10}{RC}$
	sim. & LP (Asp)	sim. & LP Asp	sim. & LP Asp Wil	?
	She Cea	Thim She RMM	Dog RMM Thi She Wil	Wil Dog RMM
	Bea	Bea-Twi Cor	Twi Cor	Twi Cor

of trees, density of cover and the percentage representation of different species were both noted. In the case of shrubs and forbs, such a close tally of cover was not considered feasible. Furthermore, during the course of the field work, several shrubs and most forbs were gradually eliminated because they were found to grow indiscriminately about all the climate stations.* These eliminations left a small but adequate list of planst that could be used as climate indicators:

Cover type	Common name	Botanical name	Field symbol
Trees	Alpine Fir	*Abies lasiocarpa*	AF
	Aspen	*Populus tremuloides*	Asp
	Black Cottonwood	*Populus trichocarpa*	BC
	Douglas Fir	*Pseudotsuga taxifolia*	DF
	Engelmann Spruce	*Picea Engelmanni*	ES
	Grand Fir	*Abies grandis*	GF
	Lodgepole Pine	*Pinus contorta*	LP
	Ponderosa Pine	*Pinus ponderosa*	PP
	Red Cedar	*Thuja plicata*	RC
	Western Hemlock	*Tsuga heterophylla*	WH
	Western Larch	*Larix occidentalis*	WL
	Western White Pine	*Pinus monticola*	WP
	White Birch	*Betula papyrifera* vars.	WB
	Willow	*Salix* sp.	Wil
Shrubs	Antelope Bush	*Purshia tridentata*	AB
	Ceanothus	*Ceanothus velutinus*	Cea
	Dogwood	*Cornus* sp. (not below)	Dog
	Rabbit Bush	*Chrysothamnus nauseosus*	RB
	Rocky Mountain Maple	*Acer glabrum*	RMM
	Shepherdia	*Shepherdia canadensis*	She
	Thimbleberry	*Rubus parviflorus*	Thi
Forbs	Bearberry	*Arctostaphylos uva-ursi*	Bea
	Cornel	*Cornus canadensis*	Cor
	Downy Brome	*Bromus tectorum*	DB
	Twinflower	*Linnaea borealis*	Twi

The cover on each plot was tabulated in the form of a fractional formula, based in part on the type of fractional code used by G. D. Hudson and others to describe landscape features elsewhere. The form of the fraction is best illustrated by an example, as follows:

Newgate—dry

$$\begin{array}{l} \text{C1}\ \dfrac{90}{\text{PP}}\ \dfrac{10}{\text{DF}} \\ \hline \text{C1}\ \dfrac{80}{\text{PP}}\ \dfrac{20}{\text{DF}} \\ \hline \text{AB} \\ \hline \text{DB Bea} \end{array}$$

The title of the fraction describes the climate station in which vicinity the plot is located, and the type of soil-exposure site—in this case Newgate station and a dry site. The four lines of the fraction proper describe the

* Four of the commonest shrubs were eliminated, namely, the two Junipers (*Juniperus communis* and *Juniperus scopulorum*), *Amelanchier alnifolia*, and *Symphoricarpos racemosus*.

virgin tree cover, second growth tree cover, shrub cover and forb cover, respectively. The symbol C1 denotes parkland tree density (Co means prairie, C2 means moderately dense forest, and C3 dense forest); letter symbols refer to plant species as described in the above table, and the numbers over the symbols refer to the percentage of total tree cover taken up by the given species. Tree symbols parenthesized are occasional on the plot. Shrub and forb species are simply listed in order of areal importance, it not being practical to try to put them on a percentage basis when many species are not being treated by the fraction.

THE VEGETATIVE COVER AT THE SEVEN STATIONS

After a suitably large set of fractions was accumulated for each site condition at each station, the content of the fractions was averaged to produce a set of representative ones for the seven stations. It was found that the cover was surprisingly consistent from plot to plot, other things being equal. Second growth tree cover was found to vary considerably about the intermediate and humid climate stations because of the widespread presence of a post-burn sub-climax of Lodgepole Pine and Aspen; in other respects the variations were small and usually understandable. In Table 2 (page 20) are given the representative fractions for five of the seven stations.

Three of the five stations represented are the dry-climate stations of Newgate, Cranbrook and Wasa. They have the same set of fractions. It was found that while there was some variation in density of trees and percentage of individuals around each station, the average for the three was the same. Hence this set of fractions can be considered as representative of the dry climate in the East Kootenay lowlands.

The fractions given for the humid climate are, of course, representative of only one station—Fernie. Similarly, the fractions for the intermediate climate are only for Elko. It is, however, notable that the vegetative cover at Elko is shown to be markedly transitional between that at Fernie and that at the dry-climate stations. Thus the virgin forest cover of Douglas Fir-Ponderosa Pine-Western Larch which prevails on moist sites at the dry-climate stations is on normal sites at Elko and on dry sites at Fernie. Similarly, on normal sites Antelope Bush, the prevailing shrub at the dry-climate stations, gives way to mixed Antelope Bush and Shepherdia at Elko (their relative importance depending on the amount of shade) and thence to Shepherdia only at Fernie. Numerous other consistencies may be noted, which add up to a clear picture of the climate-vegetation relationship for these five stations.

The cover at Kingsgate and Canal Flats is basically similar to that at Elko, the other intermediate-climate station. Thus at all three stations a virgin cover of Douglas Fir and Western Larch on moist sites gives way to a cover of Douglas Fir and Ponderosa Pine on dry sites, while Shepherdia and other shrubs give way to Antelope Bush; but certain other plants occur to give Kingsgate and Canal Flats a partially distinct cover. At Kingsgate the cover is marked by the presence on moist sites of Red Cedar, Western White Pine and Western Hemlock in even greater abundance

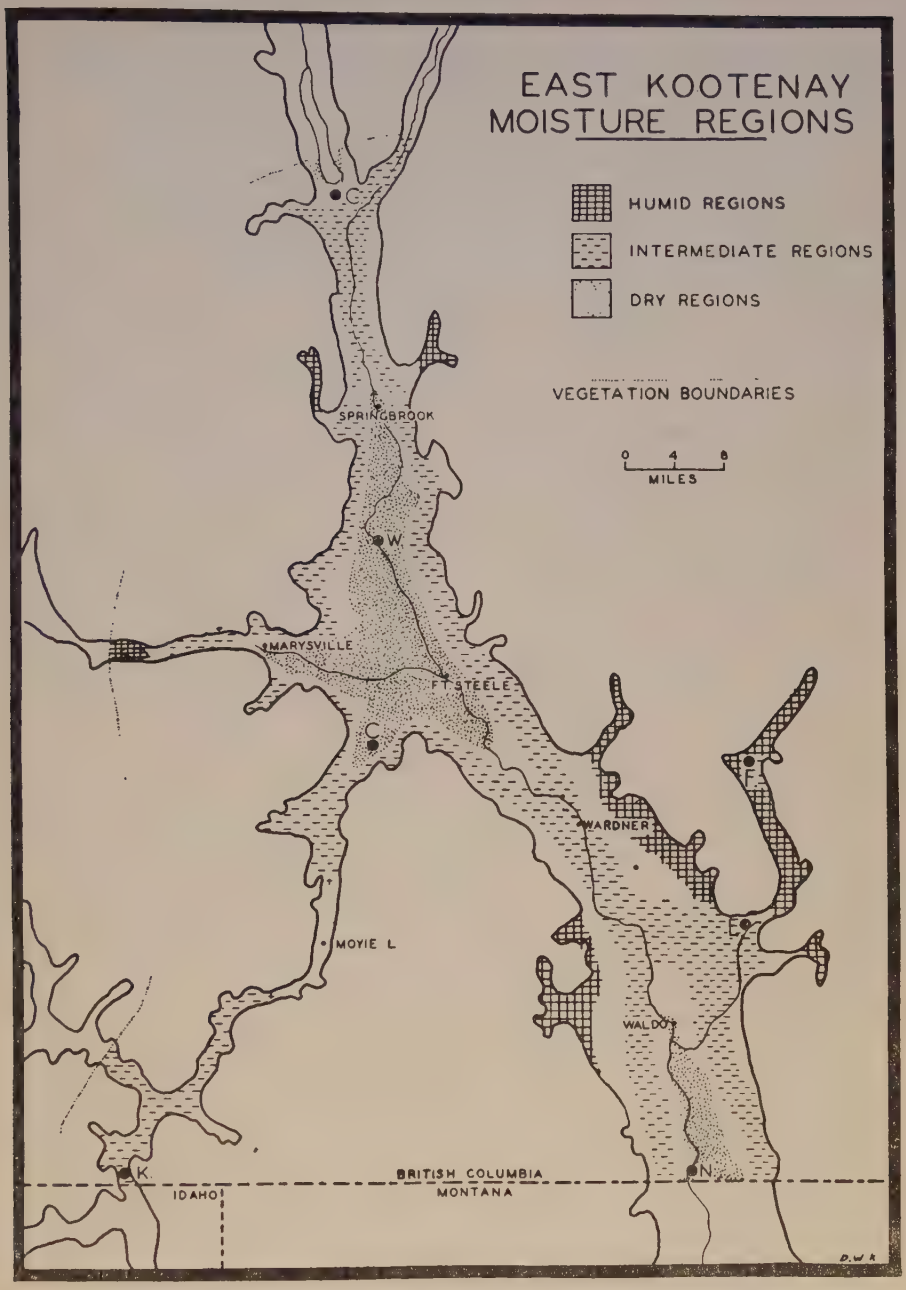

FIGURE 2

than at Fernie, and with the additional species of Grand Fir. At Canal Flats, Antelope Bush is widely displaced by Rabbit Bush, a plant almost totally absent at the other stations; and furthermore, Ponderosa Pine is relatively scarce in the face of the fact that Canal Flats has the driest climate of the three stations.

A reconnaissance of the cover immediately beyond the vicinity of Canal Flats and Kingsgate indicated that these two stations occur at points of vegetational transition caused by factors other than changes in amount of water surplus. To the west of Kingsgate, Red Cedar, Western White Pine and Western Hemlock actually become the dominants. To the north of Canal Flats, at a point approximately four miles from the station, Ponderosa Pine and Antelope Bush vanish from the landscape to be replaced by Douglas Fir and Rabbit Bush. Below the stations, in the direction of the others in the East Kootenay, the type of cover found at Elko was found to prevail. The Elko cover, therefore, may be considered as representative for the intermediate climate on the East Kootenay lowlands.

The reasons for the change in character of the cover at Kingsgate and Canal Flats have yet to be clarified. The abundance of Western White Pine, Western Hemlock, Red Cedar and Grand Fir west of Kingsgate is characteristic of the lands about the Selkirk Range, the forest on which is described by several writers as the Columbia Forest type. Low calcium content in the soil, absence of very low temperatures in winter, and relatively high humidity have been suggested as reasons for this diversity. The disappearance of Ponderosa Pine north of Canal Flats is in all probability a result of the rapid drop in winter temperatures which occurs between Cranbrook and the stations lying farther north in the Trench. But the changes are great enough that the representative fractions described for the East Kootenay stations are not applicable to neighbouring districts.

MOISTURE REGIONS OF THE EAST KOOTENAY LOWLANDS

With the aid of the representative fractions described above, it was possible to locate areas of the East Kootenay lowlands where the three known types of climate prevail. These are shown in Figure 2. Areas not shaded were found to have transitional types of cover—either alternate patches of cover typical of the three basic climates, or unusual combinations of trees and shrubs. It was considered unwise to draw linear boundaries through these areas of transitional cover, because of the possibility that some other types of climate might prevail.

The vegetational changes which were found to occur at Kingsgate and Canal Flats indicate that the fractions worked out in this paper are not immediately applicable to other districts in British Columbia. It is hoped, however, that this technique of establishing moisture regions could be applied to other districts where agricultural possibilities are great enough to make such studies of practical value.

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DIGESTIBILITY STUDIES WITH SWINE

VI. ASSOCIATIVE DIGESTIBILITY BETWEEN THE GRAIN MIXTURE AND THE PROTEIN-MINERAL SUPPLEMENT IN THE CANADIAN ADVANCED REGISTRY RATION FOR SWINE[1]

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The Canadian Advanced Registry ration for swine testing consists of the basal grains, barley, wheat and oats, with a protein-mineral supplement. The latter contains 50 per cent tankage, 25 per cent linseed oil meal, 15 per cent fish meal, 5 per cent iodized salt and 5 per cent limestone. In a previous publication (5) it was stated that the ration was being used as a basis for determining associative digestibility effects between individual feeds in swine rations. In that paper rations consisting of various proportions of barley and tankage were fed. No associative digestibility effects were found between the two feeds as far as total digestible nutrients were concerned. It was suggested that the high calcium in tankage rendered fats insoluble by forming calcium soaps. In a later publication (4) rations containing the three basal grains in varying proportions to one another were fed in digestion trials with a constant quantity of protein supplement. No associative digestibility effects were observed between the grains.

In this paper results of digestion trials in which the grain portion was fed with the protein mineral-supplement portion in varying ratios are reported. The rations are given in Table 1. The three grains, barley, wheat and oats, were fed in a constant proportion, namely 50:20:30. This grain ration was fed alone and then with quantities of protein-mineral supplement to give 5, 10, 20 and 25 per cent of the latter in the ration. The numbers were allotted to the rations at random.

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Table 1.—Constitution of rations used in swine digestion trials

Ration No.	Grain* portion in Mixture	Protein# mineral supplement in mixture
	%	%
1	95	5
2	100	0
3	85	15
4	80	20
5	75	25
6	90	10

* The grain portion contained: barley 50%, wheat 20% and oats 30%.

\# The supplement contained: tankage 50%, linseed oil meal 25%, fishmeal 15%, limestone 5%, iodized salt 5%.

TABLE 2.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN TOTAL RATIONS ARRANGED IN A 6 × 6 LATIN SQUARE (ANIMAL NUMBERS IN BRACKETS)

Nutrient	Period No.	Coefficients of digestibility in per cent, of rations containing the following percentages of supplement*						Means
		0	5	10	15	20	25	
Dry matter	1	81 (12)#	83 (11)	79 (16)	77 (15)	80 (13)	76 (14)	79.2
	2	77 (14)	79 (16)	80 (13)	78 (11)	78 (15)	76 (12)	78.0
	3	78 (16)	78 (15)	78 (14)	77 (13)	76 (12)	75 (11)	77.0
	4	78 (15)	79 (13)	77 (12)	75 (14)	75 (11)	75 (16)	76.4
	5	80 (11)	78 (14)	78 (15)	78 (12)	77 (16)	76 (13)	78.0
	6	79 (13)	78 (12)	78 (11)	75 (16)	80 (14)	76 (15)	77.8
	Means	79.0	79.2	78.5	76.8	77.7	75.6	
Organic matter	1	82 (12)#	84 (11)	81 (16)	79 (15)	83 (13)	79 (14)	81.4
	2	79 (14)	81 (16)	81 (13)	81 (11)	80 (15)	80 (12)	80.4
	3	80 (16)	79 (15)	80 (14)	80 (13)	79 (12)	78 (11)	79.1
	4	80 (15)	80 (13)	79 (12)	78 (14)	77 (11)	78 (16)	78.7
	5	82 (11)	80 (14)	80 (15)	80 (12)	80 (16)	80 (13)	80.4
	6	81 (13)	80 (12)	80 (11)	78 (16)	83 (14)	79 (15)	80.3
	Means	80.5	80.9	80.2	79.3	80.3	79.0	
Nitrogen	1	83 (12)#	84 (11)	81 (16)	88 (15)	83 (13)	77 (14)	82 8.
	2	78 (14)	80 (16)	82 (13)	79 (11)	80 (15)	82 (12)	80.4
	3	78 (16)	79 (15)	79 (14)	79 (13)	79 (12)	78 (11)	78.5
	4	81 (15)	83 (13)	80 (12)	78 (14)	78 (11)	79 (16)	79.8
	5	84 (11)	82 (14)	81 (15)	84 (12)	81 (16)	83 (13)	82.8
	6	84 (13)	81 (12)	79 (11)	78 (16)	91 (14)	80 (15)	82.1
	Means	81.4	81.5	80.5	81.0	82.2	79.8	
Ether extract	1	79 (12)#	89 (11)	91 (16)	83 (15)	93 (13)	92 (14)	88.0
	2	81 (14)	90 (16)	90 (13)	89 (11)	91 (15)	94 (12)	89.0
	3	73 (16)	86 (15)	88 (14)	95 (13)	93 (12)	93 (11)	88.0
	4	81 (15)	85 (13)	88 (12)	88 (14)	91 (11)	95 (16)	88.0
	5	77 (11)	83 (14)	84 (15)	94 (12)	95 (16)	95 (13)	88.0
	6	78 (13)	89 (12)	85 (11)	91 (16)	90 (14)	92 (15)	87.6
	Means	78.4	86.9	87.8	89.9	92.0	93.6	
Total carbohydrates	1	83 (12)#	85 (11)	80 (16)	80 (15)	82 (13)	78 (14)	81.2
	2	78 (14)	81 (16)	81 (13)	80 (11)	79 (15)	78 (12)	79.6
	3	80 (16)	79 (15)	80 (14)	78 (13)	78 (12)	77 (11)	78.6
	4	79 (15)	79 (13)	78 (12)	76 (14)	75 (11)	76 (16)	77.4
	5	81 (11)	79 (14)	79 (15)	79 (12)	79 (16)	78 (13)	79.0
	6	80 (13)	80 (12)	80 (11)	77 (16)	82 (14)	78 (15)	79.6
	Means	80.2	80.5	79.7	78.4	79.2	77.4	
T.D.N. in dry matter	1	84 (12)	89 (11)	81 (16)	81 (15)	82 (13)	77 (14)	82.4
	2	80 (14)	82 (16)	82 (13)	80 (11)	79 (15)	79 (12)	80.3
	3	80 (16)	80 (15)	80 (14)	80 (13)	79 (12)	77 (11)	79.3
	4	80 (15)	82 (13)	79 (12)	77 (14)	76 (11)	77 (16)	78.6
	5	82 (11)	81 (14)	80 (15)	81 (12)	80 (16)	79 (13)	80.3
	6	82 (13)	81 (12)	80 (11)	78 (16)	84 (14)	78 (15)	80.4
	Means	81.4	82.6	80.5	79.3	79.8	77.8	

* One decimal was kept in the individual values for the calculations but it was cut off in table to comply with editorial policy.

As explained in text, this value was not used in the statistical analysis. This was treated as a missing value.

TABLE 3.—MEANS OF COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN TOTAL RATIONS ARRANGED BY ANIMALS. (MEANS OF SIX VALUES)

Nutrient	Coefficients determined with following animal numbers, per cent					
	11	12	13	14	15	16
Dry matter	78.3	77.6	78.6	77.2	77.6	77.2
Organic matter	80.3	80.1	80.8	79.6	79.6	79.7
Nitrogen	80.5	81.4	82.5	81.0	81.6	79.8
Ether extract	87.4	89.6	89.2	87.0	86.1	89.1
Total carbohydrates	79.6	79.3	79.7	79.1	79.0	78.8
T.D.N. in dry matter	80.8	80.3	81.0	79.8	79.7	79.7

TABLE 4.—ANALYSIS OF VARIANCE OF DATA IN TABLES 2 AND 3 FOR PERIOD AND ANIMALS

Nutrient	Variance due to	D/F	Sums of Squares†	Variance†	F#
Dry matter	Period*	5	21.88	4.38	3.25
	Animal*	5	10.74	2.15	1.59
	Error	19	25.59	1.35	
Organic matter	Period*	5	25.02	5.00	3.30
	Animal*	5	6.55	1.31	‡
	Error	19	28.79	1.52	
Nitrogen	Period*	5	91.93	18.39	2.16
	Animal*	5	22.71	4.54	‡
	Error	19	161.92	8.52	
Ether extract	Period*	5	6.90	1.38	‡
	Animal*	5	60.00	12.00	1.36
	Error	19	167.98	8.84	
Total carbohydrates	Period*	5	38.83	7.77	4.35
	Animal*	5	4.22	0.84	‡
	Error	19	33.94	1.79	
T.D.N. in dry matter	Period*	5	41.04	8.21	2.43
	Animal*	5	10.51	2.10	‡
	Error	19	64.05	3.37	

Necessary F for $N_1=5$, $N_2=19$ at P of 0.05 = 2.74.
Necessary F for $N_1=5$, $N_2=19$ at P of 0.01 = 4.17.
* Sums of squares corrected according to method of Yates (6) as outlined by Goulden (2).
† Calculated to 4 decimal places, expressed here to 2.
‡ Variance less than error variance.

A description of the feeds is as follows:

(1) *Barley*—"Velvet", grown at the Experimental Farm, medium ground.
(2) *Wheat*—No. 1, Canada Western Feed, medium ground.
(3) *Oats*—No. 1, Canada Western Feed, medium ground.
(4) *Tankage*—Canada Packers Limited, Montreal.
(5) *Linseed Oil Meal*—Sherwin-Williams, Montreal, screw-press method.
(6) *Fishmeal*—Faster Fat Company, Halifax.

TABLE 5.—STANDARD ERROR OF SINGLE MEANS OF SIX VALUES FOR COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN RATIONS

Nutrient	Standard errors
Dry matter	0.47
Organic matter	0.50
Nitrogen	1.19
Ether extract	1.21
Total carbohydrates	0.55
T.D.N. in dry matter	0.75

The chemical compositions of the feeds are given in Table 7 in the appendix.

Vitamin A and D feeding oil was given during the experiment. The rations were given as a slop with water. The animals consisted of six purebred Yorkshire barrows. The live weights are given in Table 8 of the appendix.

The experiment was set up in the form of a 6 × 6 randomized Latin square. The six rations were distributed at random to the six pigs through six periods. Each period consisted of a pre-experimental sub-period of 4 days, a change-over sub-period of 3 days, a preliminary sub-period of 7 days and a collection sub-period of 10 days. The experiment commenced in January 1947 and concluded in June 1947.

PROGRESS OF EXPERIMENT

Animal 12 in period 1, receiving grain alone, was destroyed at the end of the collection sub-period. It had a distended rectum followed by rupture. This animal was replaced by another for the remaining 5 periods. The results were included in estimating the mean for the grain ration. In the statistical analysis however they were treated as missing values for each nutrient. Animal 15 in the same period had to be replaced by a new animal before the period commenced. To obtain a full preliminary sub-period the collection sub-period was reduced to five days. With animals 14 and 15 in period 3 and animals 11, 12, 13 and 15 in period 6, the collection sub-period was nine days. Animal 13 in period 4 and animal 14 in period 6 consumed their rations very slowly in the latter half of the collection sub-period. Therefore, the results for the first five days only were used. Otherwise the experiment was carried out satisfactorily as planned.

RESULTS

A summary of the results arranged in 6 × 6 randomized Latin squares is given in Tables 2 and 3. The analysis of variance with the one missing value was carried out by the method of Yates (6) as outlined by Goulden (2). This is given in Table 4. There was a significant effect between periods for the dry matter, organic matter, total carbohydrates and total digestible nutrients in the dry matter. The differences between the period means, however, were not large. There were no significant differences between the animal means. To determine if there were any associative

TABLE 6.—COMPARISON OF MEAN OBSERVED COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN TOTAL RATIONS WITH THEORETICAL ONES

Nutrient	Designation	Mean coefficients of digestibility in per cent, of rations containing the following proportions of mineral supplements			
		5	10	15	20
Dry matter	Observed	79.2	78.3	76.8	77.7
	Theoretical	78.3	77.6	76.9	76.3
	Difference	+0.9	+0.7	−0.1	+1.4
	"t"*	1.91	1.49	0.21	2.98
Organic matter	Observed	80.9	80.2	79.3	80.3
	Theoretical	80.2	79.9	79.6	79.3
	Difference	+0.7	+0.3	−0.3	+1.0
	"t"	1.40	0.60	0.60	2.00
Nitrogen	Observed	81.5	80.5	81.0	82.2
	Theoretical	80.9	80.6	80.2	80.1
	Difference	+0.6	−0.1	+0.8	+2.1
	"t"	0.50	0.08	0.67	1.76
Ether extract	Observed	86.9	87.8	89.9	92.0
	Theoretical	82.6	85.4	88.8	91.3
	Difference	+4.3	+2.4	+1.1	+0.7
	"t"	3.55	1.98	0.91	0.59
Total carbohydrates	Observed	80.5	79.7	78.4	79.2
	Theoretical	79.7	79.2	78.6	78.0
	Difference	+0.8	+0.5	−0.2	+1.2
	"t"	1.45	0.91	0.36	2.18
T.D.N. in dry matter	Observed	82.6	80.5	79.3	79.8
	Theoretical	81.5	79.0	79.2	78.5
	Difference	+1.1	+1.5	+0.1	+1.3
	"t"	1.46	2.00	0.13	1.73

* Difference divided by the S.E. of a single mean as estimated from the error variance in Table 4.
Necessary "t" for N = 19 at P of 0.05 = 2.09.
Necessary "t" for N = 19 at P of 0.01 = 2.86.

effects between the grain portion and the protein-mineral supplement of these rations the following procedure was adopted. The coefficients of digestibility of the nutrients in the protein-mineral supplements in ration No. 5 were calculated by difference using mean values for the grain ration obtained in ration No. 2. Ration No. 5 contained the highest quantity, 25 per cent, of the supplement. Using as base values the calculated coefficients of digestibility of the supplement in ration No. 5 and the values for the grain ration when fed alone, the coefficients of digestibility of nutrients in the four other mixed rations were calculated. These mean theoretical values were compared with those observed in the digestibility trials. To do this standard errors for single means of six values were estimated from the error of variance in Table 4. These errors are listed in Table 5. Using Fisher's method for unique samples (1) the differences between theoretical and observed values were divided by the respective standard errors to give "t" values. These results are given in Table 6. With the exception of the ether extract all differences were small. They were not statistically significant except for one case for dry matter and two cases for total carbohydrates. With the ether extract the differences

for rations containing 5 per cent and 10 per cent of the supplement were somewhat large. In the case of the 5 per cent the difference was statistically significant. As was suggested in the previous paper these higher values for "observed" may be purely an artefact. The content of ether extract in the grain ration was low and its apparent coefficient of digestibility may be seriously influenced by the presence of small amounts of fecal fat of body origin. When fed with the protein-mineral supplement which contains considerable fat, the effect of the metabolic fecal fat becomes negligible. To substantiate the suggestion it will be noted that as the protein-mineral supplement increased and the grain decreased, the difference between the observed and theoretical values became less. It was concluded on the basis of these results that there were no associative effects between the grain portion of the Advanced Registry Ration and the protein-mineral supplement.

On the basis of the results of these three papers, namely, Digestibility Studies with Swine, IV, V and VI, it was concluded that no associative digestibility effects existed between the components of the Canadian Advanced Registry Swine ration. Its total content in digestible nutrients and digestible crude protein is an additive function of the values of the individual components. The proportions of these components may be varied without affecting the value of the ration except in so far as a component with a higher or lower feeding value than the one it replaces will increase or decrease the total value of the mixture per unit weight.

SUMMARY AND CONCLUSIONS

1. A study was made of the associative digestibility effects between the grain portion and the protein-mineral supplement portion of the Canadian Advanced Registry Swine Testing Ration.

2. Six pure bred Yorkshire barrows were used as experimental animals.

3. Digestion trials were carried out on the grain portion fed alone and on five rations of the grain portion with the protein-mineral supplement added at rates of 5, 10, 15, 20 and 25 per cent, respectively.

4. The experiment was set up in a 6 × 6 randomized Latin square.

5. It was concluded that there were no associative digestibility effects between the grain portion of the Advanced Registry Ration and the protein-mineral supplement.

6. The results of this paper and those of the preceding two papers in the series indicate that no associative digestibility effects exist between the component feeds of the Canadian Advanced Registry Swine Testing Ration.

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APPENDIX

TABLE 7.—MEAN CHEMICAL COMPOSITION OF FEEDSTUFFS (MEANS OF SIX VALUES)

Feedstuff	Original dry matter	Chemical composition of dry matter				
		Ash	Protein*	Ether extract	Crude fibre	N.F.E.
	%	%	%	%	%	%
Barley	86.41	2.81	13.23	1.92	6.10	75.95
Wheat	86.47	2.10	15.09	1.66	3.38	77.76
Oats	87.18	3.26	12.82	4.20	12.16	67.57
Fish meal	89.64	25.52	71.80	5.46	—	—
Tankage	92.03	32.38	53.14	7.87	2.20	4.61
Linseed oil meal	92.02	5.42	32.00	7.39	8.73	46.46

* Protein factors. Grains—N × 5.83 (Jones (3)) Linseed Oil Meal—N × 5.30 (Jones (3)) Fish Meal, Tankage—N × 6.25.

TABLE 8.—LIVE WEIGHTS OF ANIMALS IN KILOGRAMS[1]

Animal No.	Weights in following periods						Gains	
	1	2	3	4	5	6	Total	Daily**
11	22	32	43	60	80	94	72	0.51
12	—*	38	50	64	84	97	—	—
13	22	33	42	57	73	85	63	0.45
14	22	31	38	57	73	86	64	0.46
15	24	37	50	67	88	105	81	0.58
16	25	37	48	66	87	100	75	0.54
Means	23	35	45	62	81	94	71	0.51

[1] Each weight is the mean of single weights before and after collection period.
* Replaced after period 1.
** 140 days, measured from middle date of two weighings in first period to middle weight of two weighings in period 6.

THE EFFECT OF SOME FERTILIZER CARRIERS UPON SEVEN GRASS SPECIES.

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During the past number of years, the seed yield of many forage crops in some areas of Ontario has dropped to where it is no longer economical for the farmers to grow some species for seed. Until the seed yields of these species are appreciably increased, a large portion of the seed sown in this province will have to be imported from other seed-producing areas. Such a practice has many drawbacks from the standpoint of economy, and moreover it usually leads to poorer stands and lighter forage yields than those given by local well-adapted strains. Consequently, this study was undertaken to see if the application of certain fertilizers would increase the seed yield on existing stands. The experiment was designed to determine the effect of five nitrogen carriers upon the seed yield of seven species of forage crops.

Anderson *et al.* (1) report that seed and forage yields of brome grass increase with the application of nitrogen up to approximately 100 pounds of nitrogen per acre. Superphosphate gave little if any response when applied to this species. Harrison and Crawford (3), also working with brome grass, found applications of nitrogen did increase seed yields, and heavy applications increased seed yields the second year, when no further treatment was applied. Musser (4) reports a response to phosphorus and potash as well as to nitrogen when applied to red fescue. He also found no significant differences between organic and inorganic nitrogen carriers. North and Odland (5) and Defrance and Odland (2), working with colonial and velvet bent, respectively, found that the seed produced was influenced chiefly by the amount of nitrogen in the fertilizer ratio.

MATERIALS AND METHODS

The five nitrogen carriers used in this study were ammonium sulphate, ammonium nitrate, sodium nitrate, calcium cyanamide, and urea. However, to reduce the possibility of a lack of phosphorous or potassium limiting seed yields, these two elements were also applied to individual plots, and the response in seed yield measured.

The five nitrogen carriers, muriate of potash, and superphosphate, were applied as side dressings to the increase seed rows of seven species. The side dressings were applied close to the row and about two inches deep. The applications were made with an experimental seeder which had been calibrated to sow forty pounds of elemental nitrogen per acre of each of the nitrogen carriers. Similarly 20 per cent superphosphate and muriate of potash were applied at the rates shown in Table 1.

For each species to be treated, uniform areas were selected early in the season before much vegetative growth was showing. The treatments were randomized in quadruplicate blocks. Each plot was $18\frac{1}{2}$ feet long, of which $16\frac{1}{2}$ feet were harvested. The increase seed rows used were three feet apart and were in their second seed-producing year in 1946.

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TABLE 1.—SOIL ANALYSIS BASED ON RAPID TESTS AND THE AMOUNT OF NITROGEN, PHOSPHATE, AND POTASH ADDED IN POUNDS PER ACRE FOR THE SEVEN SPECIES STUDIED

Species	Nitrogen		Phosphate		Potash	
	Soil Test	Added Lb./Acre	Soil Test	Added Lb./Acre	Soil Test	Added Lb./Acre
Medon Hay Timothy	40	40	T*	100	20	60
Paton Pasture Timothy	40	40	T	100	20	60
Oron Orchard Grass	40	40	T	100	20	60
Refon Red Fescue	40	40	70	30	20	60
Mefon Meadow Fescue	40	40	60	40	20	60
Kenon Kentucky Blue	40	40	50	50	60	40
Canon Canada Blue	40	40	50	50	60	40

* T = Trace.

All treatments were applied in mid-May of 1946 and again in mid-May of 1947 to Oron orchard Grass, Medon hay timothy, Paton pasture timothy, Refon red fescue, Mefon meadow fescue, Kenon Kentucky blue grass, and Canon Canada blue grass. The first three species mentioned were growing on a Burford loam soil type with a pH of 6.7; the latter four species were growing on a Guelph loam having a pH of 6.8. Both soil types were well-drained and their fertility level, as measured by rapid soil tests, is also reported in Table 1.

In order to find the residual effect of a 1946 treatment on the 1947 seed crop, additional randomized quadruplicate blocks were laid out on Oron orchard grass and Medon hay timothy, and treated in mid-May of 1946 in a manner similar to that already described.

When all species were in head in 1947 the number of seed stalks in one linear foot of the row of each plot were counted. These were analysed and correlated with seed yield.

RESULTS

Mean yields of seed of each species of grass following treatment with different fertilizer materials for the two years are shown in Table 2.

TABLE 2.—COMPARISON OF THE EFFECT OF FIVE NITROGEN CARRIERS, SUPERPHOSPHATE, MURIATE OF POTASH, AND CHECK UPON THE MEAN YIELD OF SEED OF SEVEN IMPROVED VARIETIES OF FORAGE GRASSES GROWN AT THE ONTARIO AGRICULTURAL COLLEGE, GUELPH, FOR TWO YEARS, 1946 AND 1947

Mean seed yield in pounds per acre

Treatment	Oron orchard grass	Refon red fescue	Mefon meadow fescue	Canon Canada blue grass	Kenon Kentucky blue grass	Medon hay timothy	Paton pasture timothy
Ammonium sulphate	245.2	245.2	364.2	272.9	57.0	129.9	56.3
Ammonium nitrate	256.7	220.3	355.5	398.7	67.3	144.8	62.9
Sodium nitrate	232.5	154.9	395.3	301.5	82.7	108.4	64.0
Calcium cyanamide	234.7	200.8	343.5	298.4	67.3	131.1	72.2
Urea	225.3	185.4	365.8	339.9	64.2	126.9	75.9
Muriate of potash	228.7	160.0	263.3	228.4	56.3	128.9	76.8
Superphosphate	198.1	178.1	285.8	263.4	65.3	165.2	67.4
Check	186.8	191.4	313.5	238.6	59.2	145.0	78.7
Necessary mean 5%	38.5	61.1	85.5	102.9	23.2	30.4	19.7
difference 1%	51.8	82.2	115.1	138.5	31.3	40.9	26.6

TABLE 3.—RESIDUAL EFFECT OF THE 1946 TREATMENTS UPON THE 1947 SEED YIELD WITH ORON ORCHARD GRASS AND MEDON HAY TIMOTHY GROWN AT THE ONTARIO AGRICULTURAL COLLEGE, GUELPH

Treatment	Mean seed yield of Oron orchard grass in pounds per acre	Mean seed yield of Medon hay timothy in pounds per acre
Ammonium sulphate	246.6	151.2
Ammonium nitrate	214.2	119.7
Sodium nitrate	201.6	151.2
Calcium cyanamide	214.2	119.7
Urea	233.1	176.4
Superphosphate	252.0	100.6
Muriate of potash	258.3	132.3
Check	289.8	113.4
Necessary mean difference 5%	72.5	56.2
1%	100.9	78.3

With Oron orchard grass all the nitrogen carriers (ammonium sulphate, ammonium nitrate, sodium nitrate, calcium cyanamide, and urea) and the muriate of potash treatment gave significantly higher yields of seed than the check, with the ammonium sulphate and the ammonium nitrate treatments being significant to the 1 per cent level. Differences in seed yields following the application of different sources of nitrogen were not significant.

The analysis with Refon red fescue showed no significant increase in seed yield by any of the fertilizer treatments over the seed yield of the check. However, the ammonium sulphate treatment gave a significantly higher yield of seed than the sodium nitrate treatment, superphosphate treatment, and the muriate of potash treatment. The ammonium nitrate treatment also gave a significantly higher yield of seed than the sodium nitrate treatment.

With Mefon meadow fescue the analysis showed no significant increases in seed yield by the various carriers over the yield of seed given by the check. The sodium nitrate treatment gave a significantly higher yield of seed than did the superphosphate and muriate of potash treatments. Similarly ammonium sulphate, ammonium nitrate, and the urea treatments gave a significantly higher yield of seed than did the muriate of potash treatment. There were no significant differences in the seed yield among the various nitrogen carriers.

The yield of Canon Canada bluegrass seed following the ammonium nitrate treatment showed a highly significant increase over that of the check. It also gave a yield of seed significantly higher than ammonium sulphate, superphosphate, and muriate of potash treatments. The urea treatment gave a significantly higher yield of seed than the muriate of potash treatment.

With Kenon Kentucky bluegrass the sodium nitrate treatment gave a significantly higher yield of seed than the check. It also gave a significantly higher yield of seed than the ammonium sulphate and the muriate of potash treatments.

The results with Medon hay timothy showed there were no treatments which significantly increased the seed yield above that given by the check. The sodium nitrate treatment gave a significantly lower yield of seed than that given by the ammonium nitrate, superphosphate, and check plots. The superphosphate treatment gave a significantly higher yield of seed than the ammonium sulphate, calcium cyanamide, urea, and muriate of potash treatments.

The analysis with Paton pasture timothy indicated the ammonium sulphate treatment had a depressing effect on the seed yield, giving a significantly lower yield of seed than that given by the check and muriate of potash treatments. There were no significant differences in the seed yield among the various nitrogen carriers.

Table 3 shows the residual effect of a 1946 treatment on the 1947 seed yield.

With Oron orchard grass, none of the treatments made in mid-May of 1946 was followed by higher yields of seed than the check in 1947. The check in fact gave a significantly higher yield of seed than did the ammonium nitrate, sodium nitrate, and calcium cyanamide treatments.

With Medon hay timothy the urea treatment when applied in 1946 gave a significantly higher yield of seed in 1947 than the check, ammonium nitrate, calcium cyanamide, and superphosphate treatments.

Table 4 shows the effect of the various fertilizer carriers and the check upon the mean number of seed stalks per one linear foot of row in 1947.

TABLE 4.—COMPARISON OF THE EFFECT OF FIVE NITROGEN CARRIERS, SUPERPHOSPHATE, MURIATE OF POTASH, AND CHECK UPON THE MEAN NUMBER OF SEED STALKS WITH SEVEN IMPROVED VARIETIES OF FORAGE GRASSES GROWN AT THE ONTARIO AGRICULTURAL COLLEGE, GUELPH, IN 1947

Mean number of seed stalks per one linear foot of row

Treatment	Oron orchard grass	Refon red fescue	Mefon meadow fescue	Canon Canada blue grass	Kenon Kentucky blue grass	Medon hay timothy	Paton pasture timothy
Ammonium sulphate	54.3	115.3	85.8	373.5	68.5	153.5	289.8
Ammonium nitrate	58.8	124.3	95.5	359.8	69.8	144.5	323.0
Sodium nitrate	65.8	107.0	92.0	392.8	77.8	157.0	358.8
Calcium cyanamide	72.8	102.3	85.8	399.5	84.3	149.5	342.5
Urea	57.0	114.3	90.5	439.0	66.5	146.8	372.5
Superphosphate	62.0	77.8	86.0	410.0	57.0	141.0	325.3
Muriate of potash	72.0	79.0	79.0	333.8	58.0	143.3	254.8
Check	64.3	115.8	86.8	333.5	66.8	138.0	340.5
Necessary mean 5%	16.2	44.0	43.9	154.5	28.4	27.3	100.7
difference 1%	22.0	59.9	59.7	210.2	38.7	37.1	137.0

With Oron orchard grass none of the fertilizer treatments gave a significantly different number of seed stalks than the check; however, the calcium cyanamide and muriate of potash treatments gave a significantly higher number of seed stalks than the ammonium sulphate treatment.

With Refon red fescue none of the treatments showed a significant difference in the number of seed stalks when compared with the check. The ammonium nitrate treatment, however, did give a significantly higher number of seed stalks than the superphosphate and muriate of potash treatments.

With Paton pasture timothy none of the treatments gave a significantly different number of seed stalks than that produced by the check. However, the sodium nitrate and urea treatments did give a significantly higher number of seed stalks than the muriate of potash treatment.

There were no significant differences between the number of seed stalks given by the various treatments with Mefon meadow fescue, Canon Canada bluegrass, Kenon Kentucky bluegrass and Medon hay timothy.

Table 5 shows the value of "r" for the correlation between the number of seed stems per one linear foot of row and the seed yield obtained.

TABLE 5.—VALUE OF "r" AND NECESSARY VALUE OF "r" AT THE FIVE AND ONE PER CENT POINTS FOR THE RELATIONSHIP BETWEEN THE NUMBER OF SEED STEMS PER ONE LINEAR FOOT OF ROW AND THE SEED YIELD OBTAINED, WITH SEVEN IMPROVED VARIETIES OF GRASSES GROWN AT THE ONTARIO AGRICULTURAL COLLEGE, GUELPH, 1947

Mean number of seed stalks per one linear foot of row

Variety	Value of "r"
Oron orchard grass	+.151
Refon red fescue	+.541
Mefon meadow fescue	+.535
Canon Canada bluegrass	+.424
Kenon Kentucky bluegrass	+.521
Medon hay timothy	+.110
Paton pasture timothy	+.132
Necessary value of "r" at 5% point =	±.349
at 1% point =	±.449

Refon red fescue, Mefon meadow fescue, and Kenon Kentucky bluegrass showed a highly significant positive correlation between the number of seed stalks and the seed yield. With Canon Canada bluegrass the positive relationship was significant at the five per cent point, while with Oron orchard grass, Medon hay timothy, and Paton pasture timothy the value of "r" for this relationship was not significant.

DISCUSSION

The error in this experiment was large; however significant differences did show up. No attempt will be made here to explain all the causes of this large error. It would appear, however, that insufficient replication and the inability to pick uniform stands early in the season, when little vegetative growth was showing, were at least two of the main causes.

From the results with the species tested, it appeared that at least some species will give a higher yield of seed from the application of nitrogen. All species do not respond to the same carrier, as is shown, for example, by the significant increase in seed yield due to the sodium nitrate treatment with Oron orchard grass, and the significant decrease in seed yield by the same carrier with Medon hay timothy.

The residual effect of the fertilizers upon the seed yield was not the same with Oron orchard grass as with Medon hay timothy. Why some carriers should decrease the seed yield the year following application with one species, and increase it with another, cannot be explained.

In the two years during which the experiment was conducted, no attempt was made to measure the forage yield; however, from observing the treated plots the application of the nitrogen carriers, especially with orchard grass, hay timothy, and pasture timothy, seemed to increase the leafy vegetative growth greatly.

SUMMARY

1. Seven species of grass were treated with five different nitrogen carriers at the rate of forty pounds of elemental nitrogen per acre, and superphosphate and muriate of potash at recommended rates.

2. All the nitrogen carriers and muriate of potash significantly increased the yield of Oron orchard grass seed the year they were applied. There were no significant differences between the nitrogen carriers. Some carriers significantly decreased the seed yield the year following application.

3. Ammonium sulphate increased seed yields of Refon red fescue, and gave a significantly higher yield of seed with this species than did the sodium nitrate or urea treatments.

4. With Mefon meadow fescue none of the treatments gave a significantly higher yield of seed than the check. Sodium nitrate gave a significantly higher yield of seed than the superphosphate and muriate of potash treatments. Ammonium nitrate, ammonium sulphate, and urea treatments gave a significantly higher yield of seed than the muriate of potash treatment.

5. The ammonium nitrate treatment gave a higher yield of seed than the check, ammonium sulphate, superphosphate, and muriate of potash treatments with Canon Canada bluegrass.

6. With Kenon Kentucky bluegrass the sodium nitrate treatment gave a significantly higher yield of seed than the check, ammonium sulphate, and muriate of potash treatments.

7. With Medon hay timothy no treatment increased the seed yield significantly above that given by the check the year of application. Sodium nitrate gave a significantly lower yield of seed than the check, ammonium nitrate, and superphosphate. The superphosphate treatment gave a higher yield of seed than ammonium sulphate, calcium cyanamide, urea, and muriate of potash treatments.

8. The residual effect of the 1946 treatment on the 1947 seed yield with Medon hay timothy showed that the urea treatment gave a significantly higher yield of seed than the check, ammonium nitrate, calcium cyanamide, and superphosphate treatments.

9. With Paton pasture timothy ammonium sulphate treatment gave a significantly lower yield of seed than the check and muriate of potash treatments.

10. Data on the number of seed stems per one linear foot of row for the various treatments and species were analysed and discussed.

11. There was a significant positive correlation between the number of seed stems per one linear foot of row and the seed yield obtained with Mefon meadow fescue, Refon red fescue, Canon Canada bluegrass, and Kenon Kentucky bluegrass.

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BOOK REVIEW

ADVANCES IN AGRONOMY, VOLUME TWO. Edited by A. G. Norman. Academic Press, Inc., New York, N.Y. 1950. $8.50.

Volume Two of "Advances in Agronomy" follows rather closely the general arrangement of subject matter used in Volume One. However, this second volume gives a higher percentage of space to consideration of the crop phases of Agronomy.

Volume Two begins with an excellent eighty-page discussion of the cotton crop. Practically all phases of the production of this crop are presented by experts in each field. This is followed in later sections by an informative discussion of vegetable production by experts from the University of California. Ladino clover is discussed by representatives from the Rutgers University, and the University of Illinois. An excellent contribution by Cornell University is the presentation on the preservation and storage of forage crops. The final crop presentation is on irrigated pastures. This discussion gives an interesting picture of the problems connected with the establishment and maintenance of pastures in the western areas of the United States where irrigation is the normal practice. Little consideration is given to the particular problems of the farmers in areas where portable irrigation schemes are being put into effect. However, the general principles for establishment and management would apply in both cases.

In the soil phases of Agronomy, an interesting discussion of soil nitrogen is presented by State and Federal experts in the State of Alabama. This is followed in later sections of the book by a comprehensive discussion of the Prairie soils of the upper Mississippi Valley by State and Federal representatives at the University of Illinois. The control of soil water is presented in a very enlightening manner by two workers at the School of Agriculture, Cambridge, England. Finally, there is a discussion of the reclamation of coal mine spoils. This is the problem of the treatment of the increasing areas where surface mining of coal is practised. Various means of turning such unsightly areas into productive use are presented.

On the whole, Volume Two of Advances in Agronomy is a very worthwhile addition to our agronomic literature and should be welcomed by teachers, research workers and students in the field of crops and soils.

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A NOTE ON THE INCIDENCE OF ZINC DEFICIENCY IN THE OKANAGAN VALLEY OF BRITISH COLUMBIA

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[Received for publication October 16, 1950]

Although the essential nature of zinc for plants has been recognized for many years, it has been only within the last few that a deficiency of this element has been shown to occur in some of the interior fruit-growing areas of British Columbia. It is believed that this is the first time that zinc deficiency in fruit trees has been reported in Canada. To date, the deficiency has been recognized as being present only in apple and, although very frequently only one or two limbs in an orchard show the disorder, in some instances small areas are severely affected and all trees in them show some one or more of the characteristic symptoms, viz. rosette or whorl, little leaf, and die back.

Rosette or *whorl* ("a" Figure 1) as the name implies, is a cluster of leaves caused by greatly shortened internodes on the current season's growth. Some of the leaves in the rosette may be normal in size and colour, whereas others are frequently quite small, and an interveinal chlorosis is usually present on some of them. Where the zinc deficiency is not too severe or where the tree makes a partial recovery during the growing season the rosette effect is lessened, the affected limb becomes elongated, and may even become indistinguishable from a normal one ("b" Figure 1).

Little Leaf (Figure 2) is usually found associated with the rosette condition, but occasionally it is the only characteristic symptom that is present on trees. Such leaves are found on one- and two-year-old branches and on these interveinal chlorosis is quite marked. In severe cases, the leaves are only one-half to three-quarters of an inch in length, while in extreme cases the buds fail to develop.

Die Back is an expression of zinc deficiency which, under the conditions prevailing in the Okanagan Valley, appears to be caused by low winter temperatures which kill weakened tissues.

Rosette and little leaf conditions have been controlled in British Columbia with zinc sulphate sprays—20 pounds zinc sulphate in 100 gallons of water—applied during the dormant period. In some experimental plots, response was obtained during the season following the application, but, in others, sprays in three succeeding years were necessary to effect a control.

Chemical analyses for zinc have been made on diseased and healthy leaves taken from several experimental plots. The zinc content of diseased leaves varied from 3 to 22 p.p.m. and that of healthy leaves from 6 to 40 p.p.m. on a dry weight basis.

The results reported in this letter were obtained from a co-operative experiment between the Horticultural Branch of the British Columbia Department of Agriculture and the Divisions of Botany and Plant Pathology, and Chemistry, of the Science Service, Department of Agriculture. More detailed experimental results will be reported elsewhere.

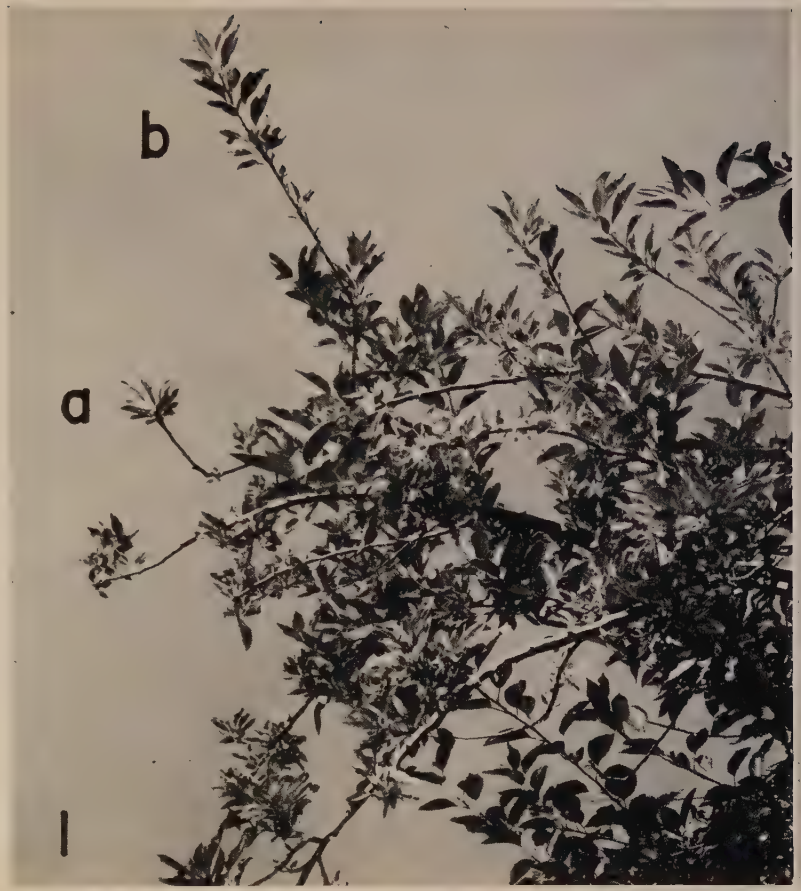

FIGURE 1. Zinc deficiency on apple. Note the characteristic rosette or whorl "a" and the partial recovery at "b".

FIGURE 2. Little leaf on apple showing the very small leaves on the one- and two-year-old wood and the rosette at the tip of the branch.

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